

FPGA ARCHITECTURE FOR LIFTING SCHEME DISCRETE WAVELET TRANSFORMS

Manasy Mariet Thomas¹, S.H.Shijini², Sumija Sukumaran³, R.Saranya⁴

^{1, 3, 4} M.E. (Embedded Systems), CMS College of Engineering

CMS Nagar, Eranapuram Post, Namakkal, India - 637 003

² Assistant Professor, Electronics & Communication Engineering,
CMS College of Engineering, Eranapuram Post, Namakkal, India

Abstract: In this paper we propose a new method towards the lifting scheme based Discrete Wavelet Transform with a new algorithm named HAAR algorithm. The operation of an image development in VLSI by FPGA kit can be completed by this technique. Here we are designing micro blaze architecture in VHDL and implementing the design in XILINX platform studio. The procedure implemented in structure using 'c' language and verified with SPARTAN 3 FPGA kit by interfacing a test circuit with PC. The connections are made by using RS 232 cable. The output images are shown in visual basic. This method reduces the number of registers, pipelines and multipliers by recombining the intermediate results during lifting scheme. So the computational complication transpired during lifting structure can also be abridged.

Keywords: XMD, RISC, SPARTAN 3 FPGA, XILINX, Discrete Wavelet Transforms, Image Decomposition.

I. INTRODUCTION

Over several past years 2 D Discrete Wavelet Transforms are widely useful for image decomposition and signal analysis in time and frequency domain. The efficiency and the quality of the image are higher compared to the traditional Discrete Wavelet Transforms. The main function of DWT is the image compression and the signal analysis. In DWT, the image can be decomposed into different sub bands based on High pass filter coefficients and low pass filter coefficients. Lifting scheme based DWT is the new method used for image compression and

signal analysis. It is a parallel processing architecture so the time requirement and the computational complexity can be reduced as compared to the traditional Discrete Wavelet Transform. Lifting scheme architectures have not only less computational complexity but also it requires less memory. This is because the parallel processing of the architecture. The number of intermediate results to be stored can be reduced as well as the no of registers multipliers and pipe lines are also to be reduced.

II. IMAGE DECOMPOSITION

The two dimensional DWT transforms an image from spatial domain to frequency domain. By applying DWT on rows of input and then the column, we can generate 2D Discrete Wavelet Transform. When DWT is applied to an image, four transform coefficients are created. The four sets are LL, LH, HL, and HH, where the L and H symbolizes a low pass filter or high pass filter for the rows and afterward letter represents the filter applied to the columns. The decomposition process can be done as different level process. The LL portion is again decomposed into four sub bands and the LL portion of that sub band is again decomposed as shown in figure 2.1. This decomposition method is stays up to three level progressions each level of wavelet decomposition to form a filter bank

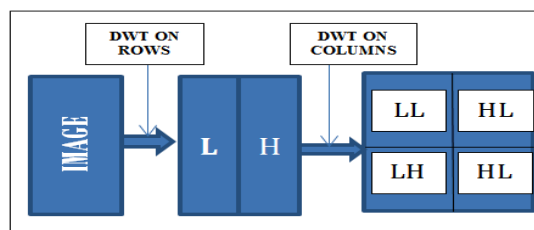


Figure 2.1 Block diagram of DWT

This filter bank is again applied horizontally to the each rows produce a sub sampled data. The first level of decomposition produces four sub sampled images. The upper and lower area represents the high pass coefficients and low passes coefficients simultaneously. Figure 2.2 represents the decomposition flow in multiple levels. Multiple levels of wavelet transform can be generated in the lowest sub band. They are represented as LL2, LH2, HL2, HH2 sub bands which generate 2-level wavelet transform.

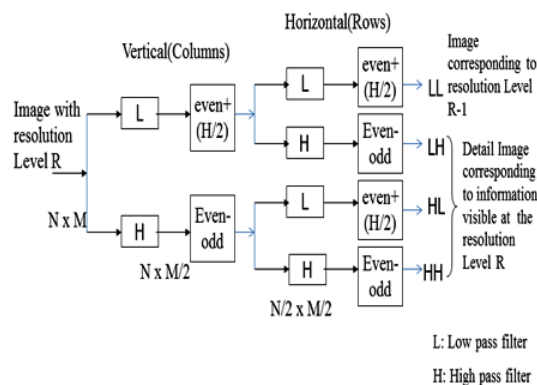


Figure 2.2 decomposition flow

In forward transform of image decomposition, the column wise processing to get H and L by the equation,

$$H = (C_l - C_h)$$

$$L = (C_h - H/2)$$

C_l is the odd column and C_h is the even column wise pixel values.

To get separate odd and even values of LL, LH, HL, HH in row wise,

$$LH = L \text{ odd} - L \text{ even}$$

$$LL = L \text{ even} - (LH / 2)$$

$$HL = H \text{ odd} - H \text{ even}$$

$$HH = H \text{ even} - (HL / 2)$$

Reverse transform is same as the forward transformation.

III. LIFTING SCHEME WAVELET TRANSFORM

Lifting scheme is a new method based on integer to integer wavelet transformation which is useful for lossless coding and reduces the computational complexity as well as the hardware requirements. Lifting scheme is a flexible tool for constructing the second generation wavelets. This process contains three stages such as split, update and predict.

1 Split step: In this stage the image coefficients can be split into even and odd signal. This is

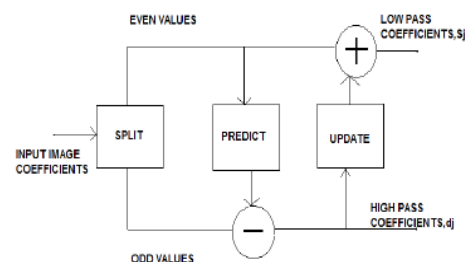
because the maximum correlation between the adjacent pixels can be needed for the predict step. Consider a pair of input samples $y(n)$ split into even $y(2n)$ and odd coefficients $y(2n+1)$.

2 predict step: In this stage even samples are multiplied by the predict factor and the outputs are added to odd samples to get the detailed coefficients (d_j) which are applied for the high pass filtering.

$$HP[2n+1] = Y[2n-1] - \left[\frac{y[2n] + y[2n+1]}{2} \right]$$

3 Update step: In this phase the thorough coefficients calculated by forecast steps which are multiplied with the update factors and the results are added to the even samples to get the coarse coefficients (s_j) results in low pass filtering.

$$LP[2n] = Y[2n] + \left[\frac{HP[2n-1] + HP[2n+1] + 2}{4} \right]$$



3.1 Forward Lifting Scheme

In forward lifting scheme, the input image coefficients are split into odd values and even values. These values are multiplied with the predict factor and added with the odd values gives the high pass filtering output. The results are multiplied with the update factor and added to the even values gives the low pass filtering outputs. The output of this forward lifting scheme process will be a compressed image without any loss of data.

Figure 3.2 represents the reverse lifting scheme process. This scheme is applied to an image for reconstructing the compressed image into the original image coefficients.

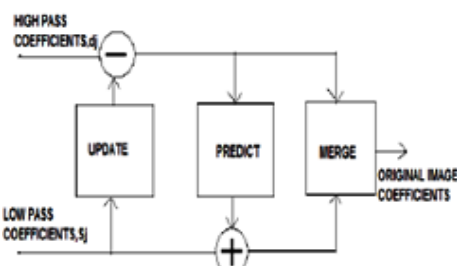


Figure 3.2 reverse lifting scheme

It is the reverse process of the forward lifting scheme. The high pass coefficients are subtracted from the update factors and multiplied with the predict factors and adding to the low pass coefficients will merge the high pass and low pass image coefficients together and gives the original image coefficients.

IV. FLOW DIAGRAM

The output of the image after applying lifting scheme DWT will be a compressed image without losing any data. When the input image is given, the pixel conversion of the image can be takes place using MAT LAB and the image coefficients are applied for the lifting scheme wavelet transform. We get a compressed image after the transformation. This compressed image can be merging to the original position by applying the inverse lifting scheme wavelet transformation. The value of this image coefficient is downloaded to FPGA kit using a JTAG and the tag will be removed after the installation. FPGA kit is connected to the system by using a RS232 cable and the output will be shown in visual basic.

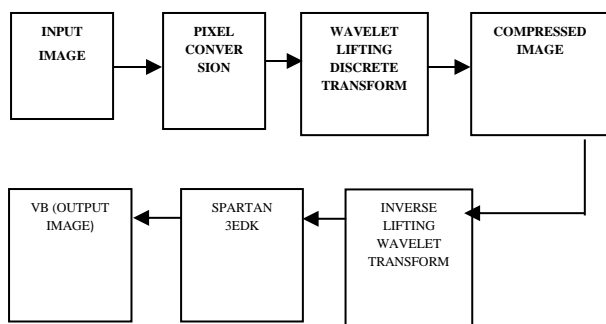


Figure 4.1 block diagram for VLSI implementation by lifting discrete wavelet transforms.

Embedded Development Kit (EDK) is an important tool used for build an embedded system in Xilinx FPGA. It enables the integration of both the hardware and software components in embedded system as shown in figure 4.2.

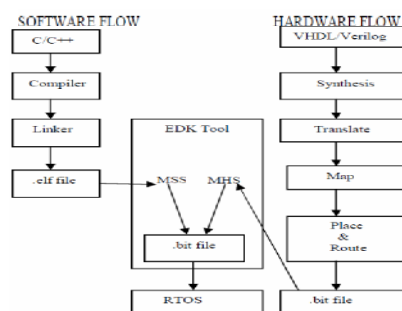


Figure 4.2 design flow

In the software side, it follows embedded software to compile the source code into an executable and linkable file format (ELF) while in hardware the design from VHDL/verilog is synthesized to gate level net list, translated to primitives and mapped on specific researches such as flip flops. The interconnection of these resources are placed and routed to maintain the timing constrains. A Microprocessor Software Specification (MSS) and a Microprocessor Hardware Specification (MHS) are used to make the connections in the hardware and software structure of the system.

V. EXPERIMENTAL SET UP

An embedded design kit typically contains a hardware platform creation, hardware platform simulation, software platform creation and software application creation and verification. Figure 4.3 shows the architecture of an embedded development kit A Microprocessor Hardware Specification (MHS) file defines the system architecture and peripherals.

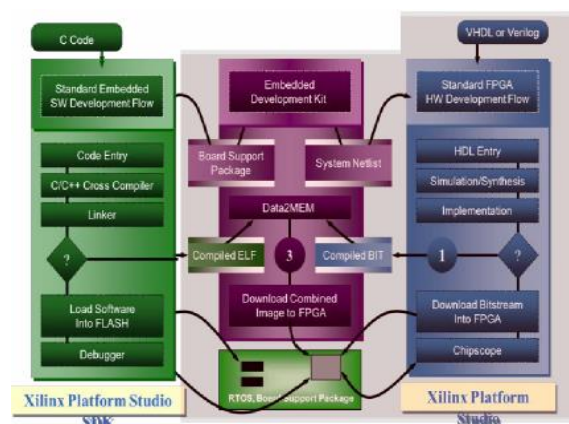


Figure 4.3 embedded development design kit

The MHS file is taken as input by the segment tool to create the simulation file for a specific simulator. GNU compiler tools are used for compiling and linking application executable for each processor in the system. Xilinx Microprocessor Debug (XMD) for debugging the application software using Microprocessor Debug Module in the embedded processor system and a software that invokes the software debugger corresponds to the compile used in the processor are the two options available for debugging the application using EDK. Xilinx Embedded Development t(EDK) is an integrated software which are used for developing embedded systems with Xilinx Micro Blaze and Power PC CPUs. The micro blaze processor is Harvard Reduced Instruction Set computer (RISC) architecture optimized for implementation in Xilinx FPGA with 32 bit instruction bus and data buses running at full speed to execute the programmes and access data from both on chip and external memory at the same time.

VI. RESULTS AND CONCLUSION

Grey levels images are mainly used as the input for applying the lifting scheme DWT. These images are 8 Bits/pixel and the size of the image is 128 x 128 as shown in figure 6.1

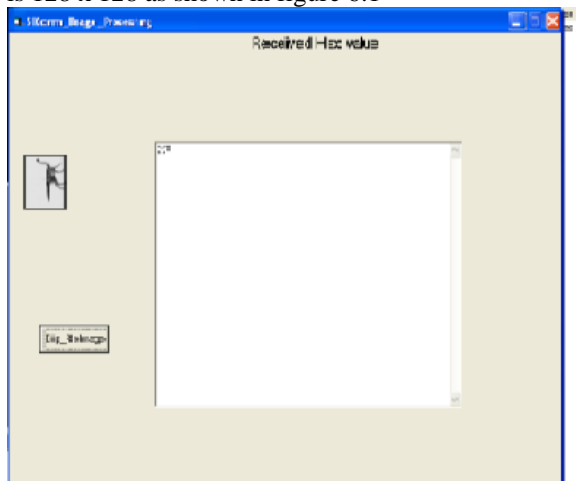


Figure 6.1 input im

The Mean Square Error value of this input image is given $MSE = ((i/p-o/p)^2)/n*m$. The total number of pixels represented as $n*m$ Peak to peak noise ratio can be calculated as $PSNR = \text{Progressive SNR} = 10 \log(255^2/MSE)$. The value of usable gray ranges from 0 to 255. The input image will be compressed in LL region of the second generation wavelet after applying forward lifting scheme process as shown in figure 6.2



Figure 6.2: compressed image

The compressed image can be merging into the original position by applying inverse Discrete Wavelet Transform to that image as shown in figure 6.3

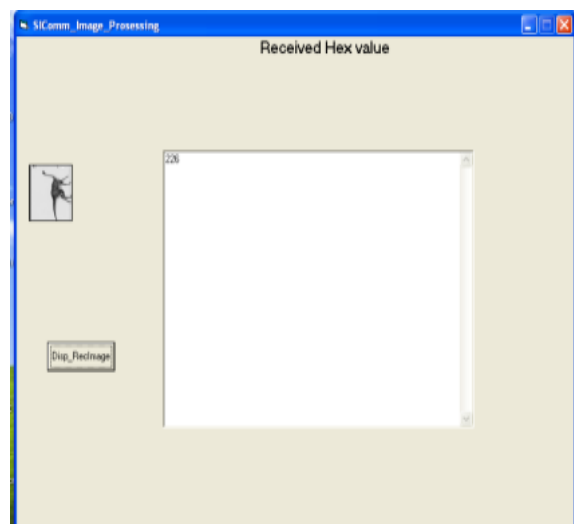


Figure 6.3 reverse DWT

VII. CONCLUSION

In this paper we propose a method of lifting scheme Discrete Wavelet Transform for the image compression and the signal analysis with a HAAR algorithm. This method can reduce the hardware complexity as well as the time requirements during the compression process without any losing of data. This operation can be performed automatically by hardware implementation using Field Programmable Gate Array kit. We can also get the Mean Square Error value and peak to peak time of the image by the use of hardware implementation.

VIII. REFERENCES

- [1] C.-T. Huang, P.-C. Tseng, and L.-G. Chen, "Flipping structure: An efficient VLSI architecture for lifting-based discrete wavelet transform," *IEEE Trans. Signal Process.*, vol. 52, no. 4, pp. 1080–1089, Apr. 2004.
- [2] C. Xiong, J. Tian, and J. Liu, "Efficient architectures for two-Dimensional discrete wavelet transform using lifting scheme," *IEEE Trans. Image Process.*, vol. 16, no. 3, pp. 607–614, Mar. 2007.
- [3] Y. Xiong, J.-W. Tian, and J. Liu, "A note on 'flipping structure: An efficient VLSI architecture for lifting-based discrete wavelet transform'," *IEEE Trans. Signal Process.*,
- [4] Daubechies and W.Sweldens, "Factoring wavelet transform into lifting steps," *J. Fourier Anal. Appl.*, vol. 4, no. 3, pp. 245–267, Mar. 1998.
- [5] G. Shi, W. Liu, and L. Zhang, "An efficient folded architecture for lifting-based discrete wavelet transform," *IEEE Trans. Circuits Syst. II, Exp. Briefs*, vol. 56, no. 4, pp. 290–294, Apr. 2009.
- [6] G. Xing, J. Li, and Y. Q. Zhang, "Arbitrarily shaped video-object coding by wavelet," *IEEE Trans. Circuits Syst. Video Technol.*, vol. 11, no. 10, pp. 1135–1139, Oct. 2001.
- [7] H. Liao, M. K. Mandal, and B. F. Cockburn, "Efficient architectures for 1-D and 2-D lifting-based wavelet transforms," *IEEE Trans. Signal Process.*, vol. 52, no. 5, pp. 1315–1326, May 2004.